C **Unit 9** C

Treatment, Storage, and Disposal of Hazardous Materials

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TREATMENT, STORAGE & DISPOSAL OF HAZARDOUS WASTE

9.1 INTRODUCTION

The treatment of hazardous waste is carried out to (1) reduce waste toxicity, (2) reduce waste volume and, or (3) reduce waste mobility. The treatment allows the waste to be more easily stored, transported and/or disposed of.   there are four main categories of treatment technologies: physical, chemical, thermal and biological.

9.2 TREATMENT TECHNOLOGIES

9.2.1 PHYSICAL TREATMENT TECHNOLOGIES

In general, physical treatment processes separate the waste stream by either applying physical forces or changing the physical form of the waste. In both cases, the chemical structure of the substances in the waste stream remains constant. The advantages of these systems are that the processes are usually simple, relatively inexpensive, and can be applied to a wide range of wastes.

Physical treatment technologies include the following.

- **Air Stripping**. A system that provides for mass transfer of organic contaminants from a liquid phase to a gas phase.

- **Mechanical Aeration/Extraction**. The process of extracting volatile contaminants from soil using aeration, often augmented with heating of soil.

- **Steam Stripping**. The use of steam for the volatilization of organic species.

- **Distillation**. A process that separates components of a liquid mixture by partially vaporizing the mixture.

- **Activated Carbon Adsorption**. The process of collecting soluble substances on the surface of activated carbon by surface attraction phenomena.

- **Evaporation**. A process where heat energy is applied to a solution, slurry or suspended solids mixture to vaporize part of the mixture while concentrating the semi-solid component.

- **Soil Flushing/Soil Washing**.   The process of extracting

contaminants from soil using washing fluids.

° **Filtration**. The removal of suspended solids from a fluid by passage through a porous media.

° **Ion Exchange**. The process of exchanging toxic ions in solution for a non-toxic ion from a solid resin.

° **Membrane Separation**. The use of specifically constructed membranes to selectively reject contaminants.

° **Phase Separation**. Application of force to remove toxic components with a specific gravity different from water.

° **Immobilization**. The process of adding materials that combine physically and/or chemically to decrease the mobility of the waste constituent.

Physical treatment processes will also produce residuals that must be disposed of in an environmentally safe manner. Treatment sludges may require additional treatment either on site or off site prior to disposal. Treatment needed may include dewatering (and subsequent treatment of wastewater) and immobilization.

The further treatment required for concentrated solids and sludges will depend on the type and level of contamination. A number of thermal, physical, chemical, and immobilization processes may be used as treatment alternatives. Liquids may also require further treatment if hazardous constituents, such as volatile organics, are present.

9.2.1.1 **Air Stripping**

Process Description

Air stripping consists of a contacting system that provides for mass transfer of volatile organic contaminants from a dilute aqueous waste stream into an air stream. Air stripping is typically applied to ground water or wastewater contaminated at low levels with volatile organics. An air stripping unit can be designed in a number of configurations to optimize air-water contact. The different types of air stripping units include:

° countercurrent packed and tray towers; and

°   diffused aeration water cascades.

The removal efficiencies of organic compounds in an air stripping unit can be predicted to some extent by Henry's Law constant (an equilibrium distribution coefficient of the individual organic's concentrations between the air and liquid or solid phases). A higher value of Henry's Law constant indicates a higher affinity of the organic compound for the air phase. In general, organics with a Henry's constant greater than 10 atmosphere can be readily air equiped.

Packed towers with air-to-liquid ratios in excess of 150 to one (volume basis) can achieve up to 99.9 percent removal of some volatile compounds from aqueous wastes while the other aeration devices have removal efficiencies between 50 and 90 percent. The system selected will depend on the physical/chemical characteristics of the waste stream and the required removal efficiency.

A modification of the stripping process is being applied to contaminated soils. The process is similar to air stripping but instead of forcing air through a packed tower medium, a vacuum is applied to pull air through the soil.

Waste Types Handled

Air stripping may be used to remove volatile organic compounds from aqueous wastes. With (Henry's Constant) greater than 10 atmosphere. Heating the influent waste stream will result in removal of less volatile organics such as ketones. In general, organic concentrations less than 1.0 percent are treatable by air stripping.

Restrictive Waste Characteristics

Air stripping is not appropriate for the removal of the following substances:

°   low volatility compounds;
°   highly soluble compounds;

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° metals; or
° inorganics.

Aqueous waste streams with high suspended solids concentrations, elevated levels of iron, manganese or carbonate may reduce packing efficiency due to precipitation and channeling.

Environmental Impacts

The following environmental concerns are associated with air stripping.

° Air stripping produces air emissions of volatile organic compounds. These emissions can be treated by capturing them using vapor phase carbon adsorption or destroying them in a fume incinerator. Estimates of stack emissions may be required as well as dispersion modeling of emissions to

determine if air emission control is necessary.

° The treated wastewater from this process may require further treatment for removal of metals and non-volatile organics.

° Periodic cleaning of packed towers may result in small quantities of metal (e.g. iron) sludge, which will require disposal.

° Dehumidification prior to vapor phase controls may result in a concentrated waste stream.

9.2.1.2 Mechanical Aeration/Extraction

Process Description

Mechanical aeration or extraction entails contacting clean air with the contaminated soils in order to transfer the volatile organics from the soil into the air stream. Note that this treatment does not remove non-volatile organics. Subsequent treatment of this air stream can be accomplished through the use of activated carbon canisters and/or water scrubbers or incineration of volatile emissions in an afterburner. A number of different methods have been employed for this process, including:

° mechanical rototilling;
° enclosed mechanical aeration systems;
° pneumatic conveyor systems;
° low temperature thermal stripping system; and
° in situ vacuum extraction systems.

Mechanical rototilling is no longer considered an acceptable alternative due to uncontrolled air emissions of volatile organics.

Enclosed Mechanical Aeration Systems

Enclosed mechanical aeration systems consist of mixing the contaminated soils in a pug mill or rotary drum system. The volatile organics are released from the soil matrix by the churning action (air/soil contact). Induced air flow within the chamber captures the volatile organic emissions and passes them through an air pollution control device, i.e. water scrubber or vapor phase carbon adsorption system. The air emissions would them be discharged through a properly sized stack.

Pneumatic Conveyor Systems

Pneumatic conveyor systems consist of a long tube or duct carrying air at high velocity, an induced draft fan to propel the air, a suitable feeder for addition and dispersion of particulate solids into the air stream, and a cyclone collector or other separation equipment for final recovery of the solids from the gas stream. Several units of this type heat the inlet air up to 300 F to induce volatilization of the organic contaminants. The typical air velocity calculated at the air exit is 75 cubic feet per second. This method allows for high air to solids ratios which can be applied for effective contaminant removal (similar to air to water ratios in packed tower air strippers). Pneumatic conveyors are primarily used in the manufacturing industry for drying of solids with up to 90% (wet basis) initial moisture content.

Low Temperature Thermal Stripping Systems

Low temperature thermal stripping systems consist of a similar configuration as the enclosed mechanical aeration except that additional heat transfer surfaces may be added for soil heating. Induced air flow conveys the desorbed volatile organic/air mixture through a combustion afterburner for the destruction of the organics. The air stream is then discharged through a properly sized stack.

Vacuum Extraction Systems

Vacuum extraction systems consist of a high volume vacuum pump connected via a pipe system to a network of boreholes or wells drilled in the contaminated soil zone. Excavation is not required for this system. The vacuum pulls air through the contaminated soils, stripping volatile organics, and the air is subsequently fed through a condenser to recover free product, and/or through an emissions control system, i.e. a water scrubber or vapor phase carbon adsorption system. The system can also serve as a monitoring system for leaks from sources such as underground storage tanks, and can recover substantial volumes of leaked chemical products.

The systems described above have been developed in the last few years in response to soil contamination problems. These systems have several advantages including:

- considerably lower cost for leasing and operation than mobile incineration systems;

° achievement of volatile contaminant removal criteria; and

° replacement of treated soil in the original excavation, or in the case of vacuum extraction, no excavation.

Waste Types Handled

Aeration/extraction may be used to strip volatile organic compounds (Henry's Law Constant) from soils or similar solids. This would include, but are not limited to:

° benzenes, toluenes, xylenes;
° TCE and other volatile solvents; and
° ketones and alcohols.

Heating the soils during the aeration process will result in accelerated rates of stripping of highly volatile compounds and enhanced removal of less volatile organics, and can produce removal efficiencies greater than 99.99%. Aeration/extraction can handle elevated levels of volatile organics in soils. Low temperature (50° C to 150° C) thermal stripping systems have handled up to 22,000 ppm total VOC with 99.99% removal efficiency.

Vacuum extraction processes can be used to remove insoluble free contaminant from the top of a water table. Air pollution control systems may not handle highly concentrated emissions effectively. Afterburner incinerations systems may be appropriate for these situations.

Restrictive Waste Characteristics

Aeration/extraction is not effective for the following:

- low volatility organics;
- high solubility compounds;
- metals; or
- inorganics.

Environmental Impacts

The following environmental concerns are associated with aeration/extraction.

- Air stripping produces air emissions of volatile organic compounds. These emissions can be treated by capturing them using vapor phase carbon adsorption or destroying them in a fume incinerator. Estimates of stack emissions may be required as well as dispersion modeling of emissions to determine if air emission control is necessary. Release to the atmosphere may not be allowed in certain locations and will require permitting in most areas.

- The scrubber effluent from the air pollution control process may require further treatment to remove metals and non-volatile organics.

- The treated soils may require additional treatment for non-volatile organics.

9.2.1.3 Steam Stripping

Process Description

Steam stripping is a unit process that uses steam to extract organic contaminants from a liquid or slurry. Direct injection of steam and multiple pass heat exchangers are the two most prevalent methods of

steam stripping. Steam stripping by direct injection of steam can be used to treat aqueous and mixed wastes containing organic contaminants at higher concentrations and/or having lower volatility than those streams which can be stripped by air. It is an energy-intensive process and the steam may account for a major portion of the operating costs.

This process is similar to steam distillation except that reflux of the stripped and recovered material does not usually occur. The process can handle a higher concentration of solids in the waste stream than a distillation unit due to the increased heat transfer surface area of the steam stripping unit. Wastes of more variable composition can also be processed more effectively by steam stripping than by distillation. One disadvantage of this process is the increased concentration of the removed volatiles. The concentrated removed volatiles will require further treatment (i.e. distillation) before reuse, or destruction by incineration.

Waste Types Handled

Steam stripping is a widely used process. The following is a list of wastes that can be removed with steam stripping from aqueous solutions and solids:

- volatile organics;
- phenols;
- ketones; and
- phthalates.

Restrictive Waste Characteristics

In general, steam stripping is effective in the removal of high concentrations of organics ranging from 1 to 20 percent.

Solids or slurries of high solids content cannot be treated by steam stripping because contact between steam and solid materials is too difficult to achieve. Water miscible organics and metal contaminants are not removable by this process.

Environmental Impacts

The following environmental concerns are associated with air stripping.

- Steam stripping produces air emissions of volatile organic compounds. These emissions can be treated by capturing them using vapor phase carbon adsorption or destroying them in a fume incinerator. Estimates of stack emissions may be required as well as dispersion modeling of emissions to

determine if air emission control is necessary.
- The treated wastewater from this process may require further treatment to remove metals and non-volatile organics.
- Periodic cleaning of packed towers may result in small quantities of metal (e.g. iron) sludge, which will require disposal.
- Dehumidification prior to vapor phase controls may result in a concentrated waste stream.

9.2.1.4 Distillation

Process Description

Distillation is a unit process that separates components of a liquid or sludge mixture by partially vaporizing the mixture and separately recovering the vapors and residue. The more volatile components of the original mixture concentrate in the vapor (distillate) while the less volatile, semi-solid components concentrate in the residue (bottoms). This process can be used for separating mixtures of organic liquids into light and heavy fractions. The light fraction can be recycled or used as a boiler fuel. The heavy fraction usually requires further processing or can be burned in a hazardous waste incinerator.

There are two principal methods by which distillation may be carried out. The first method boils the mixture to produce a vapor phase and a liquid phase which are then separated. The second method returns a fraction of condensate to the unit so that the condensate has contact with the rising vapors. Both methods may be used on a continuous or batch process. The batch process is used primarily for more viscous fluids.

Waste Type Handled

Distillation is very useful for reclaiming spent solvents from industrial processes, such as the metal finishing industries, or purifying certain aqueous, such as those heavily contaminated with organics (10,000 ppm). The following is a list of some reclaimable solvents:
- acetone;
- alcohol;
- chlorinated organics;
- hydrocarbons; and
- ketones.

Restrictive Waste Characteristics

Fractional distillation is not suited for the following waste streams:

- liquids with high viscosity at high temperature;
- liquids with a high solids concentration;
- polyurethanes; and
- inorganics.

Environmental Impact

Distillation results in two concentrated streamsCthe recovered solvent and still bottoms. The still bottoms can be incinerated or used as a boiler fuel. Metal cleaning solvents that are reclaimed by this process result in a sludge residual that may contain high concentrations of metals. Since the recovered solvents have been volatilized, incidental air emissions may become a problem.

9.2.1.5 Activated Carbon Adsorption

Process Description

The activated carbon adsorption process is one of the most frequently applied technologies for the removal of trace organic compounds from an aqueous solution. Adsorption is a surface phenomenon in which soluble molecules from a solution are bonded onto a particular substrate. Therefore, one of the most desirable properties of an adsorbent is a high surface to volume ratio. Activated carbon (with a surface to volume ratio ranging from 500 to 1400 m^2/g) is a good adsorbent for effective removal of organic compounds.

Activated carbon will adsorb most organic compounds to some degree. Factors that affect the adsorption process include:

- carbon pore structure;
- carbon contact time;
- temperature; and
- pH.

Mixtures of organics may cause significantly reduced adsorption capacity for certain compounds due to the preferential adsorption of other compounds by the carbon. Competitive adsorption of organic compounds is extremely complicated and difficult to predict. Therefore, it is recommended that pilot treatability tests be performed on the waste in question.

Gravity flow and multicolumns in series are the most commonly

designed contacting systems.

Waste Types Handled

Carbon adsorption can be applied to aqueous and gaseous wastes containing a wide range of organic compounds. The following is a list of compounds that can be successfully removed from waste streams:

- organic liquids with metals and halogens;
- organic nitrogen compounds;
- chelated heavy metals; and
- volatile organics.

Restrictive Waste Characteristics

The effectiveness of activated carbon adsorption is limited by the following waste characteristics:

- low molecular weights;
- high polarities; and
- high solubility.

The following is a list of applications for which the activated carbon adsorption process is not recommended:

- high solids content (greater than 500 mg/1);
- unassociated metals; and
- high humidity gas streams.

Environmental Impacts

The exhausted carbon will contain all of the waste constituents removed from the waste streams. The carbon must be either regenerated (on or off site) or disposed of in a secure landfill (carbon with PCBs or dioxin are not currently regenerated by the vendors). Thermal regeneration of the used carbon is the most common method currently used. Other methods of regeneration employed are solvent and steam regeneration.

Periodic backwashing of the carbon will require holding tanks for the backwash. Often the backwash is allowed to settle and the liquid portion is sent back through the carbon. The small amount of sludge generated during settling contains high concentration of organics and requires disposal.

9.2.1.6 Evaporation/Dewatering

Process Description

Evaporation is a unit process in which heat energy is applied to a liquid solution, slurry or suspended solids mixture in order to vaporize the more volatile components of the mixture. This results in a concentrated solid or semi-solid which can subsequently be handled and treated more effectively. The vapor stream is either condensed and collected or released into the atmosphere, depending upon the specific evaporation process and the volatilized components. Therefore, the primary use of evaporation is as a pre-processing step for concentrating or removing contaminants of concern.

Evaporation processes include both conventional and unconventional technologies. Individual technologies are listed below and discussed in the following paragraphs.

Conventional Technologies	Unconventional Technologies
Thin film evaporation	Carver-Greenfield process
Kettle evaporation	
Tubular evaporation	
Scraped surface evaporation	
Solar evaporation	

The most common conventional evaporation process used in the waste recycling industry today is agitated thin-film evaporation. Thin-film or wiped-film evaporators are widely used to thicken viscous liquids and slurries. Higher solids content wastes are particularly suited for thin-film evaporation. A thin-film system consists basically of a large diameter heating surface on which a thin film of material is continuously wiped. The volatile portion is vaporized, leaving concentrated semi-solids.

Other types of conventional evaporation processes include kettle, tubular, scraped surface and solar evaporators. Solar evaporation is widely practiced in arid climates. Wastewater or liquid wastes are placed in lined lagoons and evaporated by solar energy leaving concentrated solids behind.

An unconventional evaporation technology with hazardous waste applications is the Carver-Greenfield process. This process involves the addition of oil to the waste stream as a fluidizing medium to maintain liquid phase fluidity as the solids content increases. The oil is subsequently reclaimed by centrifugation and recycled.

Waste Types Handled

Evaporation can be applied as a pre-processing step or treatment process for liquids, slurries or suspended solids mixtures. Specific waste streams that may be treated by this process include:

- concentrated liquid solutions;
- highly viscous liquids;
- slurries;
- organic or metal sludges; and
- soils contaminated with volatiles.

Low boiling point components will vaporize from mixtures more easily than other components.

Wastes that may not be suitable for treatment via this process include finely divided solids which, while improving heat transfer, may be entrained in vapor. Organic materials that cause foaming and entrainment are also restricted from treatment via evaporation/dewatering.

Restrictive Waste Characteristics

Waste characteristics must be carefully analyzed for suitability. Special consideration must be given to waste characteristics that result in crystal formation, scaling, abrasion and/or corrosion.

Environmental Impacts

Two process streams are generated by evaporation processes─ a concentrated solid or semi-solid and a vapor component. Both components generally require further treatment. Vaporized liquids will also require further treatment if hazardous constituents such as volatile organics are present. If the liquid being evaporated is water, there is generally little potential for hazardous air emissions from the resulting vapor.

9.2.1.7 Soil Flushing/Soil Washing

Process Description

These processes extract contaminants from a sludge-soil matrix using

a liquid medium as the washing solution. This washing solution is then treated for removal of the contaminants via a conventional wastewater treatment system. Soil washing can be used on sludge and excavated soils fed into a contactor or washing unit. A similar process known as soil flushing can be applied on unexcavated soils (in situ) using an injection/recirculation system.

Washing fluids may be composed of the following:

- water;
- organic solvents;
- water/chelating agents;
- water/surfactants; and
- acids or bases.

After the contaminants have been removed from the washing fluid, the fluid may be recycled through the soil washing unit. In the case of in situ soil flushing, the treated washing solution may be reinjected into the soil via a recirculation system. Soils may require multiple washing/flushing cycles for effective contaminant removal. Only certain types of soils may be washed and the soil must be uniform.

Soil Washing Systems

Tank treatment systems using excavated soils can have certain advantages:

- close process control can provide more effective contaminant removal, as disaggregation of soils improves soil water contact;
- use of strong additives or washing fluids such as solvents is simplified due to the elimination of the risk of uncontrolled ground water contamination and environmental degradation; and
- smaller volumes of washing fluid are required and fluid recycling improved.

Soil Flushing Systems

These systems can be used very effectively in conjunction with mobile ground water treatment systems. Pump and treatment systems for ground water can be combined with injection of washing fluids upgradient of the extraction wells to produce accelerated flushing and decontamination of soils and ground water in situ. The treated ground water can be reinjected as a washing fluid, creating a closed loop recirculation system. Combined ground water/soil flushing systems can eliminate the costs of removing contaminated soils off site and reduce the cost of separate soil washing and ground water treatment systems.

Treatment of Washing Fluids

The leachate collected from the soil contacting process can be recycled by selecting a treatment process for the particular contaminants, e.g. air stripping of water for VOC removal. The separation of the extracted contaminants from the washing fluid can be accomplished by conventional treatment systems suited to the particular contaminants. Problems have arisen with the use of water/surfactant systems because a leachate treatment system has not yet been developed to selectively remove contaminants and pass the surfactants through intact.

Waste Types Handled

Depending on the type of washing fluid additives used for the enhancement of contaminant removal, waste types that can be removed using soil washing/flushing include the following:

- heavy metals (e.g. lead, copper, zinc);
- halogenated solvents (e.g. TCE, trichloroethane);
- aromatics (e.g. benzene, toluene, cresol, phenol);
- gasoline and fuel oils; and
- PCBs and chlorinated phenols.

Removal of each waste type is enhanced through addition of the following compounds.

Waste Type	Compound
Metals: Cations	Weak acids, reducing agents, or chelating agents (ethylene diamine tetracetic acid and citric acid)
Anions (arsenic, selenium)	Water with oxidizers (H_2O_2)
Organics (insoluble)	Organic solvents (alcohols, alkanes) or water with surfactants
Organics (soluble)	Water only, or water with surfactants

Desirable washing fluid characteristics for soil washing are listed below:
- favorable separation coefficient for extraction;
- low volatility;
- low toxicity;
- safety and ease of handling;
- recoverability; and
- treatability of washing fluid.

The areal distribution of waste types is very important in determining the effectiveness of this process. Variability of waste types can make formulation of suitable washing fluids difficult. Some contaminants may be removed effectively while others are not (e.g. solvents and metals may be difficult to remove simultaneously).

Restrictive Waste/Site Characteristics

In situ flushing systems have limitations due to the lack of close process control in the subsurface. Critical site factors include the following:

- soil characteristics
  - C highly variable soil conditions can produce inconsistent flushing;
  - C high organic content can inhibit desorption of the contaminants;
  - C low permeability (high silt or clay content) reduces percolation and leaching;
  - C chemical reactions with soil, cation exchange and pH effects may decrease contaminant mobility; and

- site hydrology
  - C ground water flow must be well-defined, permitting recapture of soil washing fluids.

These systems have experienced some problems related to solid/liquid separation subsequent to the washing phase. This is often due to the high percentage of silt or clay in the soil material. This important unit operation should be considered when evaluating the applicability of this process to a site.

Whether in situ or excavation systems are utilized, laboratory and pilot testing will be necessary to determine feasibility. Contaminant removal rates may not be adequate to reduce soil contamination below required

action levels.

Required On Site Facilities/Capabilities

All systems employing this process are mobile and are set up at the contamination site, as transportation costs for moving the soil would make this system uneconomical. Soil flushing is the most common application and if often utilized in conjunction with a contaminated ground water treatment system. The ground water is pumped out through extraction wells, treated and reinjected upgradient (sprayed above soils if in the unsaturated zone) and leached through the contaminated soil. The leachate is then recollected through the extraction wells, treated and reinjected back into the system, providing for a closed loop system.

The soil washing process includes soil washing systems such as countercurrent extraction equipment, a pug mill, or a truck-loaded cement mixer. A soil washing system treating excavated contaminated soils can provide a more effective removal process through better soil-water contact and enable less water volume to be used for an equivalent waste removal process.

Case Studies

Currently, several hazardous waste sites throughout the country are employing or plan to employ this technique for the cleanup of contaminated soils. Some have reached more developed stages than others but all have has to test this system on the site-specific conditions of concern.

A list of sites where this technology has been used includes the following.

- **Volk Air National Guard Base, Juneau County, Wisconsin**. Performed by the Air Force Engineering and Service Center, Tyndall AFB, FL 32403-6001. Soils contaminated with volatile organics were leached with water/2% surfactant and the leachate was regenerated by air stripping.

- **Lee's Farm Wisconsin** C **Battery Manufacturing**. Lead-contaminated soils were leached with water/5% EDTA and the leachate was regenerated by electrolysis.

- **Celtor Chemical Works, Hoopa Indian Reservation** C **Ore Enrichment Plant**. Tailings which include cadmium, copper and zinc.

- **Battery Dumping Pit** C **Leeds, Alabama**. Lead contaminated

soils were leached with a water/2% EDTA solution and the leachate was regenerated by sulfide precipitation.

9.2.1.8 <u>Filtration</u>

<u>Process Description</u>

Filtration may be used for two primary purposes:

- removal of suspended solids from a fluid by passage of the fluid through a bed of granular material; and
- dewatering of sludges and soils by vacuum, high pressure or gravity. Granular media filters (typically sand and anthracite) remove suspended solids through straining, physical adsorption and coagulation-flocculation. These filters may be pressurized or gravity-fed with loading rates ranging from 2 to 15 gpm/ft^2.

Various filtration methods have been employed to dewater sludges. They include:

- vacuum filtration;
- belt filter press; and
- chamber pressure filtration.

Vacuum filtration typically is a mechanically supported cylindrical rotating drum covered by a filter medium (cloth, coil springs or wire mesh fabric). Water is drawn into the center vacuum while the solids are scrapped off the drum.

The belt filter press continuously squeezes the sludge through a series of rollers apply increasing pressure and shear force on the sludge.

The chamber pressure filters consist of a collection of cloth covered plates arranged in parallel and pressed together by pressures up to 200 psi. As the plates are compressed, filtrate exits through the cloth.

Gravity-fed or pressurized granular media filter systems are less energy intensive than the three systems mentioned but require highly qualified operators with sufficient experience in backflushing operations. These systems are not applicable toward the removal of dissolved chemical species.

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Waste Types Handled

Pressurized and gravity-fed granular media filtration systems are used for waste streams containing suspended solids.

Vacuum, belt press, and chamber pressure filtration processes are primarily used to dewater sludge.

Restrictive Waste Characteristics

Energy intensive filtration operations such as belt press filtration, vacuum rotary filtration and pressure filters operate at an optimal percent solids content. Sludges which range from five to ten percent solids are ideally suited for vacuum, belt press, and chamber pressure filtration processes. Sludges with less solids content may require a pretreatment operation that will increase the solids concentration to this operational range. Pressurized and gravity-feed media filtration processes are most effective on suspended solids in the range of 100 to 200 mg/L or less. If the influent waste cannot meet these requirements, then additional prefiltration operations are required. Belt

press filtration systems require larger amounts of conditioning chemicals than the other options.

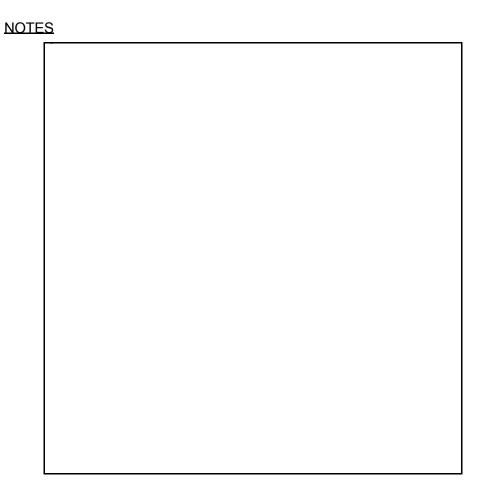### 9.2.1.9 Ion Exchange

Process Description

Anions and cations dissolved in a dilute aqueous waste can be removed from solution through the process of ion exchange. As the name implies, one ion, electrostatically attached to a solid resin material, is exchanged for a dissolved toxic ion. The exchange reaction is reversible, which allows for resin regeneration.

The exchange occurs because the divalent and trivalent toxic metal anions or cations have an increased affinity for the charged sites on the surface of the resins. These resins are originally coated with weakly held monovalent anions or cations such as chloride, hydroxyl, sodium or hydrogen ions.

Currently, the majority of new ion exchange resins are constructed of synthetic organic materials. The new resins are able to withstand a wide range of temperatures and pH and are capable of specific selectivity if ions have a high exchange capacity.

It is possible to remove both dissolved toxic anions and cations by placing a cation exchange column and anion exchange column in series. This system has the capability, depending upon the choice of resins, to remove a wide range of inorganic and organic dissolved contaminants.

Small, trailer-mounted ion exchange systems have been in operation since 1977. The typical range of pressure vessels are from two-to six-inch diameter systems up to a custom size of 12 feet in diameter. Corresponding flow rates range from 25 gpm up to a maximum of 1150 gpm. These vessels could easily be truck-mounted and moved from site to site.

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Waste Types Handled

Wastes that are suited for anion exchange include:

- all metallic anions and cations such as: $Cr_2O_7^{-2}$, SeO_4^{-2}, AsO_4^{-2}, Ni^{+2}, Cd^{+2}, or Hg^{+2};
- inorganic anions such as halides, sulfates and cyanides;
- organic acids such as carboxylics, sulfonics and some phenols; and
- organic bases such as amines.

Restrictive Waste Characteristics

The upper limits of concentration to which ion exchange may be applied are 2,500 mg/1 for dissolved ions and 50 mg/1 for suspended solids. Higher concentration levels of dissolved ion will result in rapid exhaustion of the resin with unusually high regeneration expenses. High concentrations of suspended solids will result in clogged columns. Oxidants in the waste stream should also be avoided.

Environmental Impacts

During resin regeneration, a concentrated toxic backwash stream is produced. As a result, an ion exchange system must be capable of handling this waste stream. Depending upon the waste characteristics, additional treatment of this stream, via such processes as precipitation and neutralization, will be required.

Although exchange columns can be operated manually or automatically, manual operation is better suited for hazardous waste site applications because of the diversity of wastes encountered. Manual operation requires a skilled operator familiar with the process.

9.2.1.10 Phase Separation

Process Description

Phase separation is used for separating solid/liquid or liquid/liquid suspensions with different specific gravities. It encompasses many different processes. Several of the processes that may be used for separation are described below.

- **Oil Separation**. This process employs a number of equipment configurations to remove oil from water. Each provides surface contact for de-emulsifying the oil particles from the water phase. A coalescer is a flow-through chamber with metal sheets inclined at a 45˝ angle in the middle. The metal surface enables small oil droplets to agglomerate together to form a continuous oil phase. The lighter oil fraction then travels to the top of the chamber where it is skimmed off the top.

- **Centrification**. In this process, the components of the oil/liquid mixture are separated mechanically by application of centrifugal force. Centrifugal forces are applied by rapidly rotating the mixture in a confined vessel. The suspended oils will migrate towards the center of the vessel. Centrifuges may also be used for the separation of liquid/solid mixtures.

- **Dissolved Air Flotation (DAF)**. These processes are also used to separate emulsified oils from water by first dissolving air (under high pressure) into the water and then dropping the pressure. Tiny air bubbles are generated throughout the water phase.

The oils accumulate at the air-water interface and are carried to the top of the chamber where they are skimmed off. DAF units are usually employed for more complete oil removal, whereas coalescers are used for coarse oil separation.

Waste Types Handled

The following is a list of wastes that can be treated with phase separation:

- immiscible oily liquids in water;
- suspended solids;
- hydrophobic chemicals; and
- two phase leachates.

Restrictive Waste Characteristics

Dissolved organic or inorganic contaminants will not be removed by this process.

9.2.1.11 Immobilization

The method of waste treatment discussed in this section is described by terms such as stabilization, solidification, fixation and immobilization. In general, all of these terms refer to the process of adding materials that combine physically and/or chemically to decrease the mobility of the original waste constituents. The end result of this process is to retard further migration of contaminants. Because of the similarities among the terms listed above, they are all referred to in this section by one general termCimmobilization.

Immobilization is used for several purposes which include the following:

- improvement of waste handling characteristics;
- solidification of liquid phases and immobilization of any highly soluble components;
- reduction in the potential contact area between the waste and any liquids that may come in contact with the waste to minimize leaching potential; and
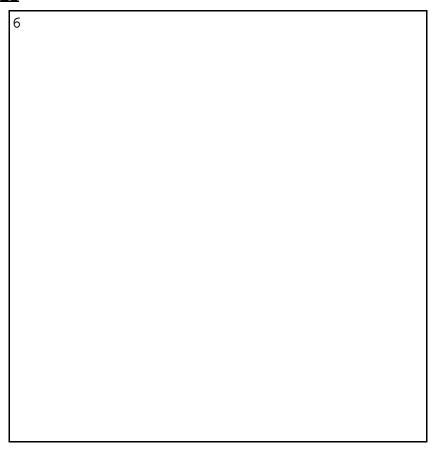- detoxification of the waste.

The process of fixation can achieve the above objectives, but the application of a specific process is dependent upon the final disposal method to be used for the waste. Some applications include:

- **in situ immobilization**Cuseful for reducing potential contaminant migration into ground water without excavation;

- **excavation and partial immobilization**C useful for improving waste handling characteristics and solidifying liquid phases prior to disposal in a secure landfill; and

- **excavation and full immobilization**C used to convert waste to a solid mass with more complete immobilization of soluble contaminants. Tests are required to demonstrate that such immobilization meets remedial action goals.

The applications above are listed in order of increasing cost. The cost is directly linked to the quantity of fixing agent (typically cement) used. Final disposal options for more complete immobilization may be less expensive than those for wastes that are partially immobilized. Disposal costs should be considered when determining the use of immobilization methods.

Portland cement (Portland Cementation) is widely used for immobilization because of its ready availability. Pozzolanic materials (Pozzolan Cementation) such as fly ash may be available at a lower cost, but the regulations on land disposal of hazardous bulk liquids prohibit the use of materials such as fly ash that do not fully immobilize the waste. The use of an immobilization

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technique should be made only after the immobilization process has been tested on sample material and the chemical and physical properties of the solidified waste have been extensively tested to insure that contaminant immobilization is adequate.

Process Description

The equipment required for this treatment includes standard cement mixing and handling equipment which is widely available.   The techniques of cement mixing and handling are well-developed and the process is reasonably tolerant of variations in the waste stream and/or soil matrix. However, modifications to the process include the use of more expensive cement types, and costly additives or coatings. In situ immobilization may require the use of special subsurface fixative injection equipment.

The key operation parameters include:

- fixative-to-waste ratio (usually 1 to 1);
- length of time for setting and curing (usually one to two days);

and
- required structural integrity and minimized potential for leaching of the pollutants from the resultant solidified waste mass.

Immobilization procedures are quite mobile. Heavy equipment such as backhoes, specialized hydraulic augers, cement mixers and dump trucks are used for specific excavation, mixing and hauling needs. Many companies have developed specialized equipment such as injectors and augers that simultaneously inject cement and mix the matrix.

Waste Types Handled

Immobilization is well-suited for solidifying sludges and soils containing the following:

- heavy metals;
- inorganics such as sulfides;
- organics (generally no more than 20% by volume);
- asbestos; and
- solidified plastic, resins and latex.

Use of sodium silicates can reduce interference with dissolved metallic anionic species such as arsenate and borate.

Restrictive Waste Characteristics

The following constituents may interfere with the use of cement-based methods of immobilizing of hazardous constituents.

- Fine organic particles such as silt, clay, lignite or other insoluble materials passing the No. 200 sieve. These particles can weaken cement bonds by coating large contaminants with a dust layer.
- Elevated levels of organics such as solvents can interfere with setting and curing of cement-based fixatives. Some vendors have processes that can handle up to 100% organics, but 20% to 40% organics is a more typical maximum.
- Soluble salts of many metals (i.e. manganese, tin, zinc, copper, and lead) as well as the sodium salts of arsenate, borate, phosphate, iodate and sulfide. These salts interfere with the setting and curing of cement as well as reduce the ultimate strength of the product.

° Sulfates which retard the setting of concrete as well as cause swelling due to the formation of calcium sulfoaluminate hydrate.

9.2.2 CHEMICAL TREATMENT TECHNOLOGIES

Chemical treatment technologies are widely used in industrial waste treatment and pretreatment. Thus, more complete descriptions of the processes can be found in the literature.

Chemical treatment processes alter the chemical structure of the constituents to produce a waste residue that is less hazardous than the original waste. Further, the altered constituents may be easier to remove from the waste stream. The chemical treatment processes presented in this section are defined below.

° **Chemical Reduction-Oxidation (Redox) Treatment**. The chemical transformation of reactants in which the oxidation state of one reactant is raised while the other is lowered.
° **Neutralization**. The interaction of an acid or base to adjust the pH of a solution or mixture to between pH 5 and 9.
° **Precipitation**. Physical/chemical process in which a dissolved contaminant is transformed into an insoluble solid and then removed by flocculation and sedimentation.
° **Dechlorination**. The addition of a chemical to remove the chlorine atoms from a hydrocarbon.

Treatment sludges from any of these processes may require additional treatment either on site or off site prior to disposal. Treatment needed may include dewatering (and subsequent treatment of water) and immobilization. Depending upon the applicable requirements, solid residuals can be disposed of on site or off site.

9.2.2.1 Chemical Reduction-Oxidation (REDOX) Treatment

Process Description

Reduction-oxidation (redox) reactions involve the chemical transformation of reactants in which the oxidation state of one reactant is raised while the other is lowered. The process destroys or reduces the toxicity of many toxic organics and heavy metals.

Use of reducing agents for treatment is less common than oxidizing agents because of the high reactivity of the reducing agents. Agents that are generally used for redox treatment include:
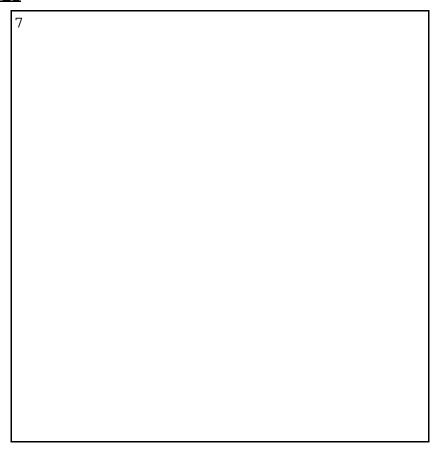
Oxidizing Agents	Reducing Agents
Ozone	Ferrous sulfate
Hypochlorite	Sodium sulfate
Hydrogen peroxide	Sulfur dioxide
Chlorine	Iron (+2)
Potassium permanganate	Aluminum
UV/ozone	Zinc
	Sodium borohydride

To ensure a complete reaction between the reactants and agents, there are specific requirements for the pH of the solution, chemical additions and rapid mixing. Some of these requirements are discussed below.

- Adequate contact between the reagents and the contaminants is crucial for an efficient chemical reaction. Therefore, special precautions must be used when applying reagents to solid materials, such as soils.
- Strong oxidizers do not discriminate between natural organics and contaminants; thus an excess amount of applied agents may be required if natural organics are present.
- Narrow pH ranges need to be maintained for optimum reaction rates.

Oxidation-reduction potential (ORP) electrodes are used to monitor the progress of this reaction.

NOTES

The equipment requirements for aqueous waste treatment are relatively simple. Potential equipment needs include:

- enclosed cylindrical tanks with rapid mix agitators to serve as the reaction vessels;
- controls such as pH meters, oxidation-reduction potential (ORP) electrodes, and metering pumps; and
- storage tanks for reagents and pH adjustment materials.

Slurries and soils may require larger reaction vessels and longer detention times than aqueous wastes. In situ methods of treatment require subsurface injection of reagents and water to contain possible violent reactions.

Waste Types Handled

Redox reactions are applied to a number of different contaminants; either oxidizing agents or reducing agents are applied to the waste in separate reaction vessels.

Redox treatment has most commonly been applied to aqueous wastes containing heavy metals. For example, water used to flush source material from soils may be treated via redox reactions.

Efforts have recently focused on applying redox treatment to slurries, sludges and soils. Applying a water-reagent mixture to sludges and soils will aid in mixing. In addition, combining this treatment with a soil flushing system may improve performance.

Wastes that can be treated via redox include:

Oxidation Treatment	Reduction Treatment
Benzene	Chromium (VI)
Phenols	Mercury
Most organics	Lead
Cyanide	Silver
Arsenic	Chlorinated organics (PCBs)
Iron	Unsaturated hydrocarbons
Manganese	

Restrictive Waste Characteristics

The effectiveness of this treatment system may be affected by a number of different waste characteristics. Some of these are discussed below.

° Presence of a wide range of contaminants may complicate the process and produce unwanted side effects. For example, if oxidation of organics is conducted in the presence of chromium (III), the chromium will also be oxidized to the more toxic and mobile chromium (VI).

° In situ soil treatment may be affected by decreased permeability of soils (due to hydroxide precipitation) or loss of adsorption capacity (due to oxidation/reduction of soil organics).

° Aqueous wastes with high organic concentrations (higher than 100 ppm) may require large volumes of oxidizing/reducing agents and costs may escalate rapidly.

9.2.2.2 Neutralization

Process Description

Neutralization is the interaction of an acid (pH less than 5) or base (pH greater than 9) with a solution with the pH of the resulting solution or mixture between 5 and 9. Neutralization can be used as a final waste treatment process, or as a pretreatment process to prepare a waste stream for further treatment. The process of neutralization is used in many commercial applications and has a wide range of applicability to waste treatment.

Neutralization can be performed using simple off-the-shelf equipment that may easily be set up as a mobile system. The equipment for neutralization usually consists of a chemical feed system and a rapid mixing process, followed by another physical/chemical process for by-product removal as appropriate. Many different equipment configurations are possible depending on the specific waste material to be treated.

Sodium hydroxide, lime or sulfuric acid are the most common reagents added to neutralize a waste. The quantity and concentration will depend on the influent and desired effluent pH. The reaction products include water, salts and solids that may precipitate.

Waste Types Handled

Neutralization is most often used on liquids, but also can be used on the following wastes:

- sludges, slurries and gases;
- organic and inorganic waste streams; and
- spent acid and alkali wastes.

Restrictive Waste Characteristics

Spent acid and alkali wastes with pH between 4.0 and 9.0 may not be effectively treated by neutralization. The concentration of the waste will determine the amount of neutralizing reagent required. Buffer capacity of the waste will also affect the dosage requirements for neutralization. For example, solids and sludges may require excessive dosages of chemicals due to the difficulty of achieving complete mixing and the potentially high buffer capacity of solid phases.

9.2.2.3 Precipitation

Process Description

Precipitation, flocculation and sedimentation will be discussed as a single process since they are commonly used together in waste treatment. They are all fully developed processes and can be rapidly applied to a variety of waste streams.

Precipitation is the physical/chemical process in which dissolved chemical species in solution (e.g. metals) are transformed into solid phases for removal. The chemical equilibrium relationships between the soluble substances are generally altered by the addition of chemicals such as lime and sodium sulfate. Additional chemicals may be needed to adjust the pH of the mixture since the solubility of metal hydroxide and sulfides is very dependent on pH.

Flocculation is a process in which small suspended particles are transformed into larger settleable particles by the addition of chemicals. Typically, the chemicals used for flocculation are alum, lime and polyelectrolytes. The flocculating agents are first readily mixed to disperse the agents; then the solution is slowly and gently mixed to allow the formation of larger particles. As with precipitation, pH is an important factor in controlling the chemical properties of the flocculating agent. As a result, pH must be monitored.

Sedimentation is the process in which suspended particles in an aqueous solution are allowed to settle under the process of gravity. The particles settle in the bottom of the sedimentation tank. The sludge is then collected and disposed of.

The equipment requirements for precipitation include:

- reaction tank with a rapid mixer;
- chemical storage tanks;
- chemical feed pumps; and
- pH controls.

Additional equipment which may be required for the dewatering of the sludge include clarifiers, filters and centrifuges.

Waste Types Handled

Precipitation is particularly well-suited for detoxifying aqueous solutions containing heavy metals and suspended solids. It has been extensively used to treat wastewaters contaminated with heavy metals. The heavy metals include:

- Arsenic
- Cadmium
- Chromium
- Copper
- Iron

- Lead
- Manganese
- Mercury
- Nickel
- Zinc

Restrictive Waste Characteristics

Organic compounds may interfere with precipitation by forming organo-metallic complexes. Cyanide and other ions may also complex with metals, reducing the precipitation potential or requiring much higher stoichiometric quantities of chemicals. Each metal salt has a different optimum pH for maximum removal and precipitation.

9.2.2.4 Dechlorination

Process Description

Dechlorination is a process in which chlorine is chemically removed from chlorinated organic compounds such as PCBs and dioxins. At present, this system is used primarily for dechlorination of transformer fluids. This chemical treatment system usually employs a sodium-based reagent composed of an alkali metal and polyethylene glycol (PEG). The mechanism for dechlorination involves nucleophilic displacement of chlorine atoms by PEG, to form an alkali metal chloride (typically KCl or NaCl) and a substituted organic polymer. By-products of this process include chloride salts, polymers, and, occasionally, heavy metals.

The reagents are air$C$ and water-sensitive. Therefore, the process should take place in a nitrogen atmosphere. The process can tolerate very small amounts of water (2000 ppm), but water content should be minimized. The reagents react immediately with chlorinated hydrocarbons, inhibitors, acids, thiols and chlorides.

A mobile dechlorination process for soils is currently under review by EPA. The system for soil treatment would contain dewatering

equipment, a heated slurry reactor, and solid-liquid separation equipment.

Current mobile dechlorination units fit on a 40-foot tractor trailer. The systems consist of the following:

- reaction vessel;
- mixing chambers;
- reagent storage tanks;
- chemical feed pumps;
- dual filter beds; and
- vacuum degasser.

Waste Types Handled

Commercially successful mobile operations have been limited to PCB-contaminated transformer fluids (organic fluids). However, efforts are being made to apply this process to contaminated soils containing PCBs, dioxins and other chlorinated hydrocarbons. Chlorinated acids and thiols have also been dechlorinated by this process.

Restrictive Waste Characteristics

Moisture content adversely affects the rates of reaction and dewatering should be a pretreatment step. Complete contact between the reagent and the soil matrix is necessary for effective decontamination, so that both reactants must be in the same phase (i.e. the soils must be in a slurry).

Contaminant concentrations are also limiting. For example, PCB concentrations exceeding 5,000 ppm cannot be treated cost effectively due to the excessive sodium requirements by this process.

9.2.3 THERMAL TREATMENT

Thermal treatment is a term associated with the use of high temperatures as the principle means of destroying or detoxifying hazardous wastes. There are several thermal processing methods, some of which are well-developed and proven, others that are in the development stage. The three major thermal processing modes are:

- incineration;

- pyrolysis; and
- wet oxidation.

Incineration involves the controlled combustion of organic wastes under net oxidizing conditions (i.e. the final oxygen concentration is greater than zero) and encompasses most of the well-developed thermal technologies. In pyrolysis, thermal decomposition occurs when wastes are heated in an oxygen deficient atmosphere.

Wet oxidation is a thermal processing mode in which organic materials are broken down through the use of elevated temperatures and pressures in a water solution or suspension. The processes that utilize the basic principles of wet oxidation and have been applied to hazardous waste treatment are supercritical water oxidation and wet air oxidation.

The advantages of thermal treatment include:
- volume reduction;
- detoxification;
- energy recovery; and
- materials recovery.

Thermal treatment offers essentially complete destruction of the original organic waste. Destruction and removal efficiency (DRE) achieved for waste streams incinerated in a properly operated thermal processes often exceed the 99.99 percent required by RCRA for most hazardous wastes. Hydrogen chloride (HCl) emissions are also easily controlled. Furthermore, available air pollution control technologies can effectively address the potential for particulate emissions.

Ash/detoxified soil/solid treatment residuals	May require further treatment (e.g. immobilization) and/or disposal in secure landfill, sanitary landfill, or on site.
Aqueous waste streams (e.g. scrubber liquor, separator bottoms)	May be discharged to nearby municipal or industrial sewer; or may require treatment (e.g. neutralization, precipitation/ sedimentation) on site or off site; if treated on site, need to address disposal of residuals (see above).
Off-gases	May be discharged through a stack after treatment by air pollution control equipment to remove particulates and acid

gases. Oxygen (O_2) and carbon monoxide (CO) concentrations are continuously monitored within the stack to assure compliance with regulatory requirements.

9.2.3.1 Rotary Kiln Incineration

Process Description

Rotary kiln incinerators are thermal treatment systems utilizing a rotary kiln as the primary furnace configuration for combustion of solids. The major components comprising a rotary kiln system typically include:

- solids feed system;
- rotary kiln;
- secondary combustion chamber or afterburner;
- air pollution control units; and
- process stack.

Process operation involves the introduction of wastes and auxiliary fuel into the high end of a cylindrical, refractory-lined kiln. As they pass through the kiln, wastes are substantially oxidized to gases and ash. Operating parameters within a mobile kiln and typical ranges are:

Temperature: 1200° F - 1800° F
Residence Time: Seconds for gases; up to hours for solids

Residence times of the feed solids within any given kiln are controlled by four factors:

- rotational speed of the kiln;
- inclination of the kiln;
- feed rate; and
- kiln internals (e.g. dams, chains, "bellys").

Exhaust gases from the kiln enter a secondary chamber afterburner operating at temperatures between 1400° F and 2400° F to complete oxidation of the combustible waste. Prior to release to the atmosphere, exhaust gases from the afterburner pass through air pollution control units for particulate and acid gas removal.

Ash residue and solids are discharged at the bottom end of the kiln. Depending upon the remaining contaminant levels, residuals may require further treatment (such as solidification) prior to final disposal.

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Waste Types Handled

Most types of solid, liquid, and gaseous organic wastes can be treated. Containerized wastes and oversized debris are more difficult to handle in smaller transportable size kilns than non-containerized wastes and therefore must be processed to an acceptable size.

Particular wastes processed include:
- PCBs;
- dioxins;
- soil contaminated with organics;
- halogenated organics;
- nonhalogenated organics; and
- pesticides.

Restrictive Waste Characteristics

Waste characteristics that are not suited for mobile rotary kiln systems include:

    °   high inorganic salt (e.g. sodium sulfate) content which cause degradation of the refractory and slagging of the ash; and

    °   high heavy metal content which can result in elevated emissions of heavy metals which are difficult to collect with air pollution control equipment.

Mobile Rotary Kilns

The EPA-ORD has operated a mobile rotary kiln system with a thermal capacity of 15 million Btu per hour, approximately one-fifth the capacity of large, fixed industrial installations. This unit has successfully destroyed PCB wastes as well as a number of other RCRA-listed wastes. The ORD unit may be available for use at other CERCLA sites.

The EPA-ORD mobile system is self-contained on three semi- trailers, each equipped with air suspension systems for reduced road shock loads. The first trailer carries a shredder, hydraulic ram feed system, and the rotary kiln. The second trailer carries the afterburner or secondary combustion chamber and a water quenching system. The third trailer contains a particulate scrubber, a mass transfer scrubber, an induced draft fan, process stack, and a diesel-driven generator. Proposed modifications call for replacement of the particulate scrubber with an electrostatic precipitator. Each trailer and system configuration were specifically designed to meet both length and weight requirements for interstate highways.

9.2.3.2 Liquid Injection Incineration

Process Description

Liquid injection incinerators consist of a refractory-lined combustion chamber and a series of atomizing devices, usually fluid (i.e. air or steam) atomized nozzles. These devices introduce waste material into the combustion chamber in finely divided droplets vigorously mixed with air. Following combustion, the flue gases are cooled and treated with air pollution control devices to remove particulates and to absorb acid gases. Complete combustion requires adequate atomization of the waste in order to provide for efficient mixing with the oxygen source. Pretreatment, such as maceration and blending, may be required for wastes that may be difficult to atomize, vary in heat content, or are not pumpable.

Waste Types Handled

This process can be applied to almost all pumpable, atomizable organic wastes. Particular contaminants processed include:

- liquid PCBs;
- halogenated organics;
- non-halogenated organics;
- pesticides;
- Pumpable acid and phenolic sludges; and
- dioxins.

Restrictive Waste Characteristics

Waste characteristics that are not suited for liquid injection systems include:

- high inorganic salt content;
- high moisture content;
- high heavy metal content; and
- nonpumpable sludges, solids and soils.

Wastes with high moisture content are not restricted in all cases. Depending on the waste stream, high moisture content may be beneficial in reducing system temperature while allowing the same thermal input. In all cases the waste stream must be free of (or pre-processed to remove) solids which prevent pumping and satisfactory atomization or which fuse at incineration temperatures and attack (flux) refractory material or sublime/vaporize to yield a hard-to-collect fume.

9.2.3.3 Fluidized Bed Incineration

Process Description

Fluidized bed incinerators are refractory-lined vessels containing a bed of graded, inert granular materialᶜ usually silica sand. The heated bed material is expanded by combustion air forced upward through the bed. As waste material is injected radially and mixed with the hot fluidized bed material, heat is rapidly transferred to the waste feed. When the waste dries and burns, heat is transferred back to the bed. Excess air requirements are reduced because of the high degree of turbulence in the bed which ensures thorough mixing between combustion gases and the waste feed. Bed depths of fixed commercial scale sized facilities are typically three feet while at rest and six feet during operation. Any inorganic materials in the waste stream are entrapped in the bed which necessitates continuous removal and make-up of bed material.

Secondary combustion chambers (including the freeboard volume above the bed) are always used to give additional time for complete combustion. Off-gas treatment following the secondary reaction chamber is dependent on the waste feed and may include a wet scrubber, baghouse or electrostatic precipitator (ESP).

Operating parameters for mobile fluidized bed units are:

Temperature: 1400″ - 1800″ F
Residence Time: Bed-minutes
                          Freeboard and secondary combustion chamber-seconds

Developers have indicated that higher operating temperatures (1600″ - 2400″ F) are possible without causing bed defluidization problems.

A variation in fluidized bed technology has been applied to waste disposal and is referred to as *circulating bed combustion*. Unlike a conventional fluidized bed which has a fixed bed depth, high velocity air introduced at the bottom of the refractory-lined combustion chamber transports the bed out of the fluidization zone. Subsequently, the eluted solids are captured and partially returned to the fluidization zone. This results in entrainment of wastes and subsequent combustion along the entire height of the combustion section. Complete destruction is reported to be attained at relatively low temperatures because of this high degree of turbulence. Secondary combustion chambers are said not to be required because of the high degree of destruction. Off-gases pass through a cyclone which captures and recycles solids (and perhaps, ground limestone which can be added for acid gas control) to the combustion zone through a nonmechanical seal. The combustion gases pass through a heat recovery system and baghouse filter or other air pollution device prior to discharge to a stack.

Operating parameters for mobile circulating bed combustors are:

Temperature: 1400″ - 1800″ F
Residence Time: Gases - 2 seconds
                          Solids - minutes to hours

The application of conventional fluidized bed and circulating bed systems to treat hazardous wastes is based on extensive operating experience for coal, refinery sludge, paper mill sludge and sewage

sludge combustion.

Waste Types Handled

Applicable wastes include organic solids, sludges, slurries and liquids. Particular wastes that may be processed include:

- contaminated soil;
- halogenated organics;
- non-halogenated organics;
- PCBs;
- pharmaceutical wastes; and
- phenolic wastes.

Restrictive Waste Characteristics

Waste characteristics that are not suited for fluidized bed systems include:

- oversized pieces of waste that cannot be shredded to less than one inch in size for circulating bed combustors and less than three inches for fluidized bed combustors;
- high sodium content which can cause degradation of the refractory and slagging of the ash;
- high heavy metal content which can result in volatilization of the metals and unacceptable emission levels; and
- low-melting point constituents ($<1600 °F$) that may cause operational difficulties.

Pretreatment such as grinding and size reduction is particularly important in order to provide a uniform character/size feed and conditions such that solids removal from the bed is possible.

9.2.3.4 Plasma Arc

Process Description

The principle of plasma arc technology involves breaking the bonds between organic constituents. This is accomplished in an atomization zone where a co-linear electrode generates a plasma or electric arc that is stabilized by field coil magnets. As low pressure air passes through the arc, the electrical energy is converted to thermal energy by the activation of air molecules into their ionized atomic states. When the excited atoms and molecules relax to lower energy states, intense ultraviolet light is emitted. The energy from the decaying plasma is transferred to passing atomized waste materials reducing them to their elemental constituents. An equilibrium zone is provided for the controlled cooling and recombination of the atomic species to form

simple non-hazardous molecules such as hydrogen, carbon, carbon monoxide and hydrogen chloride.

Process units comprising a plasma arc system include:

- plasma generator;
- reactor vessel consisting of atomization and equilibrium zones; and
- air pollution control equipment.

System operation parameters include:

- Atomization zone   Temperature   >10,000˚ F
                           Residence time   500 microseconds
- Equilibrium zone   Temperature   1700˚ - 2700˚ F
                           Residence time   1 - 2 seconds

Since the process is pyrolytic (i.e. takes place in absence of oxygen), the scale of the equipment is small considering the high throughput rates. This characteristic makes it potentially attractive for use as a mobile unit. The application of plasma arc technology to hazardous waste treatment is hindered by a lack of operating experience. At this time, the only operating plasma arc system that is beyond the research and development stage is a pilot-scale mobile unit.

Waste Types Handled

This process is applicable to liquid (pumpable) organic wastes and finely divided, fluidized sludges. It may be particularly applicable to the processing of liquid wastes with a high chlorine content. Contaminants processed include:

- PCBs;
- chlorinated organics; and
- other complex organics.

9.2.3.5 Supercritical Water Oxidation

Process Description

The supercritical water oxidation process is based on the ability of water to perform as an excellent solvent for organics when the water is above its critical temperature (705˚ F) and critical pressure (3200 psi).

When air is mixed with aqueous wastes above the critical temperature and pressure of water, organics are reported to be rapidly and completely oxidized to CO_2 and water. In addition, inorganic salts become almost insoluble above $930\,°F$ and precipitate out of the supercritical liquid. The exothermic conditions during the oxidation reactions produce energy in excess of process energy requirements and, in principle, allow for the production of high pressure steam or electricity.

Process operation involves the use of a high pressure pump to bring an aqueous solution or slurry of hazardous wastes up to system pressure before being heated to supercritical conditions in a feed-effluent heat exchanger. Large organic molecules are thus broken down to molecules of low molecular weight. High pressure air is then injected into the reactor, rapidly oxidizing the lower molecular weight compounds. Bases such as sodium hydroxide are added to the waste to neutralize any inorganic acids formed during oxidation.

The supercritical water oxidation process can be adapted to a wide range of feed mixtures and scales of operation, making it a potentially feasible mobile technology. However, supercritical water oxidation is a relatively new thermal technology and therefore has limited operating experience. To date, operating experience has been restricted to bench-scale and pilot-scale systems. The pilot-scale system is skid-mounted and capable of being transported. Commercial-scale systems are reportedly under design.

Waste Types Handled

This technology can be applied to aqueous solutions or slurries with organic concentrations from 1 to 100 percent. The actual organic concentration of the waste fed to the process will depend on the heating value of the original waste material. The heat content of waste fed to the process is controlled at 1800 Btu per lb. Therefore, wastes with a heating value below 1800 Btu per lb require the addition of auxiliary fuel. Waste material with a heating value above 1800 Btu per lb requires either the addition of dilution water or blending with a lower heating value waste.

Particular contaminants and wastes processed include:

- PCBs;
- dioxins;
- solvents;
- pesticides; and
- still bottoms and tank bottoms.

9.2.3.6 Wet Air Oxidation

Process Description

Wet air oxidation is a thermal treatment technology which breaks down organic materials by oxidation in a high temperature and pressure aqueous environment and in the presence of compressed air. The resulting exothermic reactions are self-sustaining and potentially capable of generating steam as a by-product.

In this process, wastes are mixed with compressed air. The waste-air mixture is then preheated in a heat exchanger before entering the corrosion-resistant reactor where exothermic reactions increase the temperature to a desired value. The exit stream from the reactor is used as the heating medium in the heat exchanger before it enters a separator where the spent process vapors (i.e. non- condensable gases consisting primarily of air and carbon dioxide) are separated from the oxidized liquid phase.

The reactor or pressure vessel is sized to accommodate a specific waste flow over a certain amount of time. Residence time, temperature, pressure and possibly a catalyst are based upon the characteristics of the waste.

Wet air oxidation technology has been used extensively for industrial applications. Utilization of this technology for hazardous waste is more limited. There are, however, several full-scale fixed facilities treating hazardous waste.

Waste Types Handled

This process can be applied to dissolved or suspended organic substances in the form of liquid wastes and sludges.

Particular contaminants and wastes processed include:

- halogenated organics;
- inorganic/organic sludges;
- contaminated ground water;
- inorganic/organic cyanides;
- phenols; and
- leachates.

Restrictive Waste Characteristics

Non-pumpable aqueous wastes and highly halogenated wastes are restricted from this process. Minimum and maximum chemical oxygen demand (COD) concentrations for a feasible application are 10,000 milligrams per liter and 200,000 milligrams per liter, respectively.
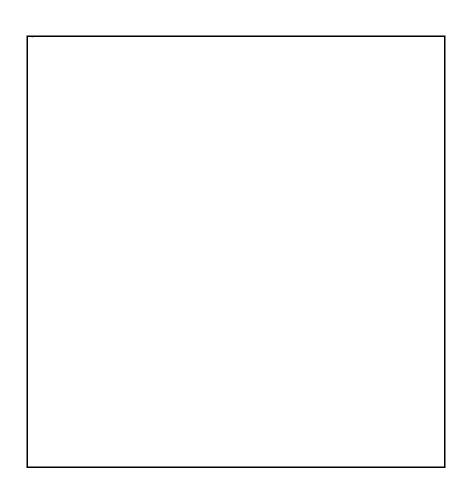
9.2.4 BIOLOGICAL TREATMENT

Several well-developed biological technologies exist for the treatment of aqueous waste streams contaminated at low to moderate levels with non-halogenated organics and some halogenated organics. Addition of powdered activated carbon significantly improves treatment performance and permits removal of non-biodegradable organics such as pesticides or herbicides. In addition, enhanced in situ biodegradation is being developed for sites having soil and ground water contaminated with readily biodegradable organics.

The basic processes available are included below.

- **Aerobic Biological Treatment**. Tank-based processes using oxygen metabolizing microorganisms and careful process control for low-strength aqueous waste streams.

- **Anaerobic Biological Treatment**. Tank-based processes using microorganisms capable of chemical biodegradation in the absence of oxygen. Careful process control and extended retention time required.

- **In Situ Biodegradation**. Use of existing indigenous aerobic bacteria or introduced cultured strains in soil. Activity is often accelerated with addition of nutrients. Biodegradation of organics in soil or ground water may require from 6 to 18 months.

Aerobic and anaerobic tank-based processes will generate residual biomass sludge which will require further treatment and disposal. Vendors of mobile biological units can design and/or provide systems for treatment and disposal, which may utilize thermal, physical, chemical or immobilization processes.

9.2.4.1 <u>Aerobic Biological Treatment</u>

<u>Process Description</u>

Aerobic biological treatment consists of conventional activated sludge processes as well as modifications of these processes including:

- sequential batch reactors;
- rotating biological contactors;
- trickling filters; and
- fixed film reactors.

All of these systems can treat aqueous waste streams contaminated with low levels of non-halogenated organics and/or certain halogenated organics. Addition of powdered activated carbon can significantly

improve treatment of halogenated organics. Readily available mobile units include:

- compact fixed film reactors;
- fluidized bed reactors; and
- membrane reactors utilizing filtration and biomass recycling.

Waste Types Handled

Mobile, tank-based aerobic reactors can handle many non-halogenated organics according to several vendors of this process (*Superfund Treatment Technologies: A Vendor Inventory*, EPA, 1986). Efficient operation may require use of specially cultured bacterial strains. A few of the organics that may be handled by this system are listed below:

	Concentration	Removal Efficiency
Phenols	up to 350 mg/L	99%
Formaldehyde	up to 300 mg/L	99%
#2 Fuel Oil	up to 300 mg/L	98%
PCP	up to 20 mg/L	90%

Low levels of heavy metals are often removed through adsorption to the biomass.

Addition of powdered activated carbon may permit treatment of aqueous waste streams contaminated at low to moderate levels with:

- pesticides and herbicides;
- halogenated hydrocarbons; and
- halogenated solvents.

Restrictive Waste Characteristics

Biological reactors require stable operating conditions. Abrupt changes in waste stream characteristics can generate shock loading to the biomass. The maintenance of stable levels is crucial for a number of key environmental parameters in the waste stream, including:

- dissolved oxygen (1 to 3 mg/L minimum);
- pH (6 to 8);
- nutrients (phosphorous, nitrogen, carbon);
- alkalinity (provides buffering capacity);
- minimal levels of suspended solids (particularly for fixed film reactors); and
- liquid retention times of 2 to 5 hours.

Mobile biological reactors can be used for ground water treatment due

to the relative stability of ground water characteristics.

The biomass is susceptible to elevated levels of heavy metals or halogenated organics. These may be overcome with the addition of the following:

° powdered or granular activated carbon; or
° pretreatment using physical/chemical treatment units to remove problematic waste types.

Pilot studies are necessary to determine process feasibility on specific wastes.

Environmental Impacts

Settled sludge and/or excess biomass residues may contain elevated levels of organics or heavy metals. Sludge will require dewatering and may be shipped off site for disposal at a treatment and disposal facility.

Use of activated carbon for removal of halogenated organics will produce a mixture of spent carbon and biomass sludge as residuals. Treatment can include:

° dewatering and removal off site; or
° carbon regeneration and sludge destruction using wet air oxidation.

Generation of undesirable odors or the driving off of volatile organic compounds from the aeration tasks may necessitate the use of special venting and filtering procedures for gases.

9.2.4.2 Anaerobic Digestion

Process Description

Anaerobic digestion is a biodegradation process capable of handling high strength aqueous waste streams that would not be efficiently treated by aerobic biodegradation processes. Advantages of anaerobic systems over aerobic systems include:

° capability to break down some halogenated organics;
° low production of biomass sludges that require further treatment and disposal; and

° low cost.

However, anaerobic systems can be less reliable than aerobic systems. For this reason, aerobic systems are better suited for mobile unit applications. Disadvantages of anaerobic systems include:

° potential for shock loading of biomass and termination of biodegradation process due to variation in waste stream characteristics;
° low throughput due to the slow biodegradation process (two steps);
° frequent necessity for further treatment of effluent prior to discharge off site or to a municipal treatment system; and
° generation of methane gas (a problem if it cannot be readily used on site for meeting energy requirements).

Careful design and control can often solve these problems, but vendors are reluctant to recommend anaerobic mobile systems. Anaerobic systems are more susceptible to variation in waste stream characteristics and environmental parameters. Fixed anaerobic systems are widely used in industry for treatment of uniform, concentrated biodegradable waste in aqueous waste streams due to the low cost, low residual generation and production of usable methane gas. However, application to variable CERCLA waste streams is relatively infrequent. Anaerobic systems have the best potential as pretreatment step for an aerobic system that would otherwise be unable to process a high strength waste such as a leachate.

Waste Types Handled

Anaerobic digestors can handle concentrated waste streams with biodegradable nonhalogenated organics and moderate levels of halogenated organics. The most suitable application may be as a treatment step for landfill leachates where storage, mixing and flow regulation can be accomplished prior to introduction to the digestors.

Anaerobic digestion can partially break down some halogenated organics unsuitable for aerobic digestion. Anaerobic systems can also be used as a pretreatment step prior to aerobic biodegradation. Recommended influent characteristics for anaerobic processes are listed below.

° BOD   1000 to 15,000 mg/L
° COD   >1500 mg/L

Restrictive Waste Characteristics

As with aerobic systems, the biodegradation process can be slowed or

halted by the following:

- abrupt change in waste stream characteristics;
- variable environmental conditions (e.g. temperature, pH);
- elevated levels of heavy metals or halogenated organics toxic to the biomass; and
- inadequate nutrient levels.

9.2.4.3 IN SITU BIODEGRADATION

Process Description

In situ biodegradation is a process that uses existing indigenous aerobic bacteria, or introduced cultured strains of bacteria, to biodegrade organic compounds in soil or ground water. Since the biodegradation process occurs below water or ground surface, precise process control is not feasible. However, the biological process may be accelerated by introducing supplemental materials, including:

- nutrients (phosphorous, nitrogen);
- oxygen; and
- cultured bacterial strains.

In situ biodegradation is often used in conjunction with a ground water pumping and reinjection system to circulate nutrients and oxygen through a contaminated aquifer and associated soils. It can provide substantial reduction in contaminant levels in soils and ground water at a fraction of the cost of soil excavation and/or above-ground pump and treat systems.

Waste Types Handled

To date, in situ biodegradation has been applied to sites contaminated with readily biodegradable nonhalogenated organics, primarily gasoline. Applications can include the following waste types:

- gasoline and fuel oils;
- hydrocarbon solvents (e.g. benzene, toluene, xylene);
- nonhalogenated aromatics (e.g. ethylbenzene, styrene, phenol, cresol); and
- alcohols, ketones, ethers and glycol.

The most common applications have been at gasoline spill sites where

conventional excavation and/or treatment methods are very costly.

Before in situ biodegradation can be used, wastes must be evaluated for:

- biodegradability;
- oxygen requirement;

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- nutrient requirement for biodegradation;
- solubility;
- inhibitory effects at various concentrations; and
- total quantity contained on site.

Restrictive Waste Characteristics

In situ biodegradation is generally inhibited by:

- halogenated organics;
- elevated levels of metals; and
- elevated levels of inorganics such as chlorides, acids, or caustics.

Site Requirements

A number of site-specific factors are critical in evaluating the potential for use of in situ biodegradation on that site. These include:

- site geology;
- soil characteristics, including
  C permeability,
  C pH,
  C moisture content,
  C organic content;

- aquifer characteristics and hydrogeology;
- water quality parameters, including
  C dissolved oxygen,
  C pH,
  C alkalinity,
  C available nutrients; and
- subsurface temperatures.

In general, suitable sites would meet the following criteria:

- site geology and hydrology allowing for ready pumping and extraction of contaminated water, followed by reinjection and recirculation;
- soils with neutral pH, high permeability and moisture content of 50 to 75 percent; and
- water quality parameters in ranges such that inhibition of biological activity does not occur.

9.3 STORAGE

9.3.1 ACCUMULATION REGULATIONS

The EPA allows a generator to accumulate (not store) hazardous waste on-site for a specified time and within specified volume limits without requiring the generator to obtain a RCRA TSD Facility permit. However, if a generator exceeds these limits then the generator must obtain a TSD permit and comply with all the applicable design and operational requirements for a TSD facility. The accumulation regulations are based on quantity of waste produced and set the time and volume limits for shipping the waste off site.

9.3.1.1 **Quantity**

The generator status is based on the volume of hazardous waste generated over on a monthly basis.

Generator Status	Quantity/Month
° Large Quantity Generator (LQG)	> 1000 kg
° Small Quantity Generator (SQG)	100 - 1000 kg
° Exempt SQG	< 100 kg

However, if a generator produces more than 1 kg of acute hazardous waste (P List Waste) in any month then they become a large quantity generator regardless of other waste production. If a container is disposed of with the waste then the weight of the container must be included. In general, a 55 gallon drum of waste weighs approximately 200 kg. However, the weights could be significantly greater depending on the type of waste (i.e., heavy metals).

9.3.1.2 **Time Limits**

The EPA allows a generator to accumulate (not store) hazardous waste on-site for a specified time without requiring the generator to obtain a RCRA TSD Facility permit. The accumulation time limits are based on the quantity of waste the facility generates during a monthly period. The accumulation date starts when the waste is first placed in the container and *not* when the container is full. An exception to this rule is with satellite accumulation areas which are explained in a following section.

Generator Status	Time (days)
° Large Quantity Generator (LQG)	90
° Small Quantity Generator (SQG)	180
if waste is transported > 200 miles	270
° Exempt SQG	none

9.3.1.3 **Volume Restrictions**

The EPA has also set quantity limits that a RCRA regulated facility cannot exceed with obtaining a TSD permit. The limits are outlined below.

Generator Status	Quantity (kg)
° Large Quantity Generator (LQG)	none
° Small Quantity Generator (SQG)	6000

° Exempt SQG   1000

9.3.1.4 <u>Satellite Accumulation Areas</u>

The EPA allows a generator to accumulate waste near the source of waste generation without affixing the accumulation start date when accumulation begins (satellite accumulation rule). However, several conditions must first be met.

- ° The satellite accumulation area must be at, or near, the source of generation.

- ° The satellite accumulation area must be under operator control.

- ° The container must be < 55 gallons (1 qt if acute)

- ° The container must be properly labeled (EPA and DOT)

The accumulation start date is not affixed until the container becomes full, or is moved from the satellite accumulation area to the accumulation area.

9.3.2   CONTAINER MANAGEMENT

Hazardous waste are frequently accumulated in drums, containers, and/or tanks. In the past, many of the containers that stored hazardous waste leaked, resulting in soil and ground water contamination. For this reason, the EPA has established regulations for container management. Container management regulations can be found in 40 CFR 264 Subpart I (Use and Management of Containers). In general, container management requirements cover five main areas: condition of containers, compatibility of waste, management of containers, inspections and containment.

9.3.2.1 <u>Condition of Containers</u>

All containers must be in good condition. If a containers shows signs of structural defects and/or leaks the contents must be transferred to a container that is in good condition.

9.3.2.2 <u>Compatibility of Waste</u>

All containers must be made of or lined with a materials which will not react with the hazardous waste to be stored so that the ability of the

container to contain the waste is not impaired.

9.3.2.3 Management of Containers

A container holding hazardous waste must always be closed during storage, except when it is necessary to add or remove waste. Containers must be opened, handled and stored in such a manner which prevents rupturing the container or cause it to leak.

9.3.2.4 Inspections

All containers must be inspected at least weekly. The inspection is to determine leakage or deterioration of the containers and the containment system. Inspection records become part of the operating record of the facility and must be available for regulatory agency review.

All containers must be properly labeled with both DOT hazard class labels and EPA Hazardous Waste Labels. The EPA label must have the generator information, DOT proper shipping name, manifest number, and EPA ID # for the waste, and accumulation start date. An exception to this rule is if the container is in a "satellite accumulation" area. In this case, only a hazardous waste label which identifies the contents and a DOT hazard class are necessary.

9.3.2.5 Containment

All storage areas must have secondary containment systems. The system has specific design requirements that include:

- base must be free of cracks;
- floor must be sloped or containers raised;
- sufficient capacity to contain 10% of the total volume stored or 100% of the largest container, whichever is greater; and
- run-on must be avoided and any spills or precipitation must be removed in a timely manner.

In addition, ignitable and reactive wastes must be stored at least 50 feet inside the facilities property boundary. Incompatible waste must be separated from other materials by a dike, berm, wall or other device.

9.3.3 UNDERGROUND STORAGE TANKS

The primary reason for regulating underground storage tanks is to protect ground water. Underground storage tanks are defined as having greater than 10% of the volume underground, including all plumbing (line) systems.

Specific requirements for tanks that are used to treat or store hazardous waste include:

- assessment of existing tank system's integrity;
- design and installation of new tank system or components;
- containment and detection of releases;
- general operating requirements;
- inspections; and
- response to spills and leaks.

These requirements are covered in detail in 40 CFR 264 and 265 Subpart J (Tank Systems).

9.4 DISPOSAL

9.4.1 MANIFEST SYSTEM

The Uniform Hazardous Waste Manifest is utilized to maintain a record of all hazardous waste from "cradle-to-grave". A Uniform Hazardous Waste Manifest (manifest) must be used whenever hazardous waste is transported from the site where the waste was generated It is the generator's responsibility to insure that manifest contain all the proper information. The manifest is described in more detail in Unit 8 of this training manual.

9.4.2 DISPOSAL METHODS

9.4.2.1 **Landfills**

Landfills are utilized for final disposal of waste. Landfills are often the repositories for residues of various treatment methods (i.e., incinerator ash, sludges, etc.). Prior to placement in a hazardous waste landfill, all waste must pass the Toxic Characteristics Leaching Procedure (TCLP) and the Paint Filter Liquids Test (PFLT).

Hazardous waste landfills have very stringent requirements for design, construction, operation and closure. These requirements have been established to protect ground water. The requirements for hazardous waste landfills are contained in 40 CFR 264 and 265 Subpart N (Landfills). A few of the more relevant requirements include the following.

- **Design and Operating Requirements**C all new landfills must install two or more liners and a leachate collection system

above and between the liners.

The lower liner must be constructed of at least 3 feet of compacted clay with a permeability of less than 1×10^{-7} cm/sec. The final cap must have a permeability equal to the liner system.

Maintain run-on and run-off control systems

° **Monitoring and Inspections**C Liners must be inspected during construction to insure tight seams and joints. During operation landfill weekly inspection of run-on/run-off systems and the presence of leachate in and proper functioning of leachate collection and removal systems.

° **Surveying and Recordkeeping**C The exact location and dimensions of each cell and the locations of contents of each cell must be accurately surveyed.

° **Closure and Post-closure care**C Post closure periods are for a minimum of 30 years. During that time, the owner/operator must ensure compliance with all maintenance and all monitoring requirements. The regulatory agency has the option of extending the post-closure monitoring period beyond 30 years.

9.4.2.2 Land Treatment

Land treatment units have been historically utilized by the oil and gas industry to land farm (land treat) petroleum wastes. Under RCRA a land treatment program must be designed to ensure that hazardous constituents placed in the treatment zone are degraded, transformed, or immobilized within the treatment zone. The method of treatment is based on utilizing natural occurring, or inoculated microorganisms that are capable of degrading the waste.

Due to the potential for subsurface migration of contaminants, there are stringent requirements for land treatment units. Since the passage of the 1984 Hazardous and Solid Waste Amendments (HSWA) to RCRA, land treatment has become greatly limited due to the land disposal restrictions (LDR's).

RCRA has established requirements for land treatment units which include:
° treatment demonstration;
° design and operating requirements;
° unsaturated zone monitoring;
° recordkeeping; and

° closure and post-closure care.

9.4.2.3 Deep Well Injection

The EPA has established five categories for injection of liquid wastes: Classes I, II, III, IV and V.

Class I wells are those used to inject hazardous waste liquids into a formation which is beneath the lowermost formation containing an underground source of drinking water within one-quarter mile of the injection well.

Class II injection wells are utilized by the oil and gas production industry. these may be used for disposal of liquids brought to the surface during production or for the injection of materials to enhance the recovery of oil and gas.

Class III injection wells are used by the mining industry for in situ mining of ore bodies. This is frequently utilized for solution mining for uranium, salts and potash.

Class IV injection wells are utilized for injection of hazardous waste and radioactive waste into or above a formation that has an underground source of drinking water within one-quarter mile of the injection well. This class of injection well is no longer obtainable.

Class V injection wells are those not identified in Classes I, II, III, or IV.

9.4.2.4 Salt Mine (WIPP)

The Waste Isolation Pilot Plant (WIPP) located outside Carlsbad, New Mexico has been designed and constructed to act as the national repository for tranuranic (TRU) waste disposal. The TRU waste will be shipped from waste storage areas of the U.S.Department of Energy nuclear weapons complex. The waste, once received, will be disposed of approximately 2000 feet below the ground surface in the middle of a 2000 foot Precambrian salt deposit. The salt deposits will eventually encapsulate the waste materials.

9.5 TSD MANAGEMENT CONSIDERATIONS

9.5.1 WASTE MINIMIZATION/WASTE REDUCTION

The development and implementation of a waste minimization/ waste

reduction program should be the key focus for all environmental management programs. By reducing the amount of hazardous waste generated a facility greatly decreases its cost associated with waste handling and disposal (liability, costs for disposal, compliance reporting, training, etc.). Waste minimization and waste reduction are covered in more detail in Unit 11 of this training manual.

9.5.2   WASTE EXCHANGE

In some situations a waste may be exchanged with another company for use as a raw material or for treatment of hazardous waste. For example, a highly acidic waste may be exchange with another industries high base waste (high pH). The result is the elimination of both hazardous waste and a large savings to both industries. To try and facilitate waste exchange, a number of clearinghouses have been established